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Assessment of current and proposed nature reserves of Mexico based on their capacity to protect geophysical features and biodiversity

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Abstract

Mexico currently has 144 nature reserves covering approximately 9.1% of its land area. These reserves were established for a variety of reasons—often unrelated to the protection of biodiversity. In 2000 in response to a growing concern about the lack of organized conservation reserve planning to protect the important threatened biological and physical features of Mexico, the Mexican Commission for Knowledge and Use of Biodiversity (CONABIO) proposed the establishment of 151 new reserves for Mexico covering 51,429,500 ha. We compiled a GIS analysis using digital thematic maps of physical and biological features to examine how the existing and proposed reserves serve to protect the biodiversity and physical features of the country. Using a conservation target of placing a minimum of 12% of the land area of each important biophysical feature in nature reserves, we found that the 144 existing nature reserves covering 18 million ha (9% of the country) only meet that target for elevation ranges >3000 m and areas with poor soils. These mountainous areas represent less than 1% of the country. The gaps in the existing nature reserves network occur mainly at lower and intermediate elevations (<3000 m) areas with xeric, tropical, and temperate ecosystems, and high productivity soils. The areas proposed by CONABIO increase the proportion of protected lands in the country to over 27% and most of the conservation targets for geophysical features, and land cover, categories are met. Whether this area would be sufficient to maintain viable populations and ecological integrity of species and ecosystems is unknown. Even with the new reserves, low elevation coastal lands would be below the conservation target in the nature reserves. To include a representative sample of these lands would be difficult as these are the same areas where the majority of people live.

Keywords: Conservation planning; GAP; Gap analysis; Nature reserves

1. Introduction

One of the most important goals for conservation biologists is the protection of biodiversity within a given geographic area. Nature reserves play a vital role in achieving this goal. In 2000, there were about 30,000 protected areas on earth, encompassing over 13,250,000 km^2. of the land surface and representing about 8% of land area of the planet. A much smaller proportion of the world's seas (0.25%) are protected (Green and Paine, 1997; Orian and Soulé, 2001). One of the first steps in assessing how well reserves achieve their goal of preserving biodiversity, is to investigate the extent to which specific resources are being protected within the existing reserve system (Scott and Csuti, 1997). Considerable effort has been made in recent years to compile databases of protected areas and to quantify the level of protection given to different resources and ecological units within these areas (Caicco et al., 1995, DellaSala et al., 2001). Much of this work has taken place in the United States, where efforts to compile geographic-databases of protected areas and of the resources they contain have been largely conducted under the umbrella of the US Geological Survey's Gap Analysis Program (Scott et al., 1993) and the Nature Conservancy (Stein et al., 2000). Using these data Wright et al. (2001) found that 66% of the vegetation types mapped across 10

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western states of the USA had <10% of their areas contained in strictly protected nature reserves.

The compilation of protected area databases and their associated resources has generated much debate on how much land in a given area should be dedicated to nature protection. The figures 10 and 12% are widely cited as the percentage of a nation that should be dedicated to nature reserves (World Commission on Environment and Development, 1987; Noss, 1996). We have found no evidence to prove that either figure is scientifically defensible. In fact, the few assessments of the area required to sustain ecological processes or to maintain viable populations of native species are often two–six times higher (Noss, 1993, Cox et al., 1994, Soulé and Sanjayan, 1998).

Mexico is considered the most biodiverse country in Latin America and the Caribbean (Dinerstein et al., 1995), and ranks fourth in the world after Indonesia, Brazil and Colombia in terms of species diversity (Toledo, 1988; Mittermeier, 1988). Mexico has approximately 30,000 species of plants including 21,600 species and 2500 genera of flowering plants (Rzedowski, 1993). Mexico supports 449 mammalian species of which 142 are endemic. Mexico is also among the top 10 countries in the world for the number of restricted-range bird species and endemic bird areas it supports (ICBP, 1992). Fifty-three percent of the nation's reptiles (out of 693 existing species) and 45% of the amphibians (of 285 existing species) are endemic. Currently the Mexican threatened species regulation NOM-059-ECOL-2001 (SEMARNAT, 2002) includes 2,583 species of conservation concern. This biological richness results from great habitat variation, diverse ecological regions, complex topography, climate, geology and geographical location. Mexico, like Indonesia, bridges two major biogeographic realms, the Nearctic and the Neotropical, which provide exchanges between elements of northern temperate and tropical origins (Rzedowski, 1978).

Mexico's topography varies from high plateau in the central regions (1,000–1,800 m) to coastal plains (0–600 m), with complex mountain systems in between (Ferrusquia-Villafranca, 1993) (Fig. 2).

Two workshops (1996 and 1999) were conducted by the National Commission for Knowledge and Use of Biodiversity (CONABIO) with the support of the World Wildlife Fund (WWF), the US Agency for International Development (USAID), the Nature Conservancy (TNC) and the Mexican Nature Conservation Fund (FMC) to aid in determining conservation priorities for Mexico based on biological characteristics of specific areas (Arriaga et al., 2000; CONABIO, 2000). Analyses were made by 32 natural resources specialists from 17 Mexican universities and research centres, using digital cartographical information that included the existing natural protected areas, topography, elevation, land use and land cover, sub-watersheds, hydrological priority regions, ecoregions and town locations. The commission identified 151 terrestrial areas throughout the country for the protection of biodiversity that covered about 51,429,500 ha.

Mexico currently has 144 nature reserves covering about 17,904,000 ha or about 9.1% of the country. These areas range in size from El Sabinal (8 ha) to Valle de los Cirios (2,656,400 ha). The establishment of nature reserves in Mexico began 125 years ago. These reserves were established for a variety of reasons—including scenic and recreational, and their establishment was often unrelated to protection of biodiversity. In addition, in many of these areas enforcement of regulations prohibiting, for example, consumptive uses of resources has been non-existent. Only for 30 of the 144 reserves have management programs designated policies for use of the reserve (CONANP, 2002). There is at present little information available about the resources in these reserves. Thus the degree that those reserves serve to protect important elements of biodiversity in the country is unknown. Approximately 62% of the area in the existing reserves are contained in the areas identified by CONABIO (Fig. 1).

Efforts to identify gaps in the nature reserves networks have been conducted using biological (Scott et al., 1993) and enduring physical features (Hunter et al., 1988). We used both in conducting this assessment of the adequacy of existing and proposed nature reserves. Our broad objective was to determine how well the current and proposed Mexican nature reserves capture different elevation zones, soil types, potential vegetation types, and land use and land cover of 1996 of the country.

2. Methods

We created digital maps of the existing 144 Mexican nature reserves and of the 151 proposed reserves. Thematic maps for elevation zones (INEGI et al., 1990), soil types (INIFAP and CONABIO, 1995), potential vegetation types (Rzedoski, 1990), land use and land cover (INE and INEGI, 1996), and the boundaries of proposed terrestrial reserves, were obtained from CONABIO (www.conabio.gob.mx). The geographical limits of the 144 existing Mexican nature reserves were provided by the National Commission of Natural Protected Areas (CONANP; Fig. 1).

We analyzed all data sets using ArcInfoTM version 8.02 and ArcViewTM version 3.2 software. Differences in map scales ranging from 1:250,000 to 1:4,000,000 and differences in map projections for the various data sets caused the area estimates calculated for the different characterizations of our study area to vary slightly. However, considering the large area of the analysis, we did not consider these differences to be significant.

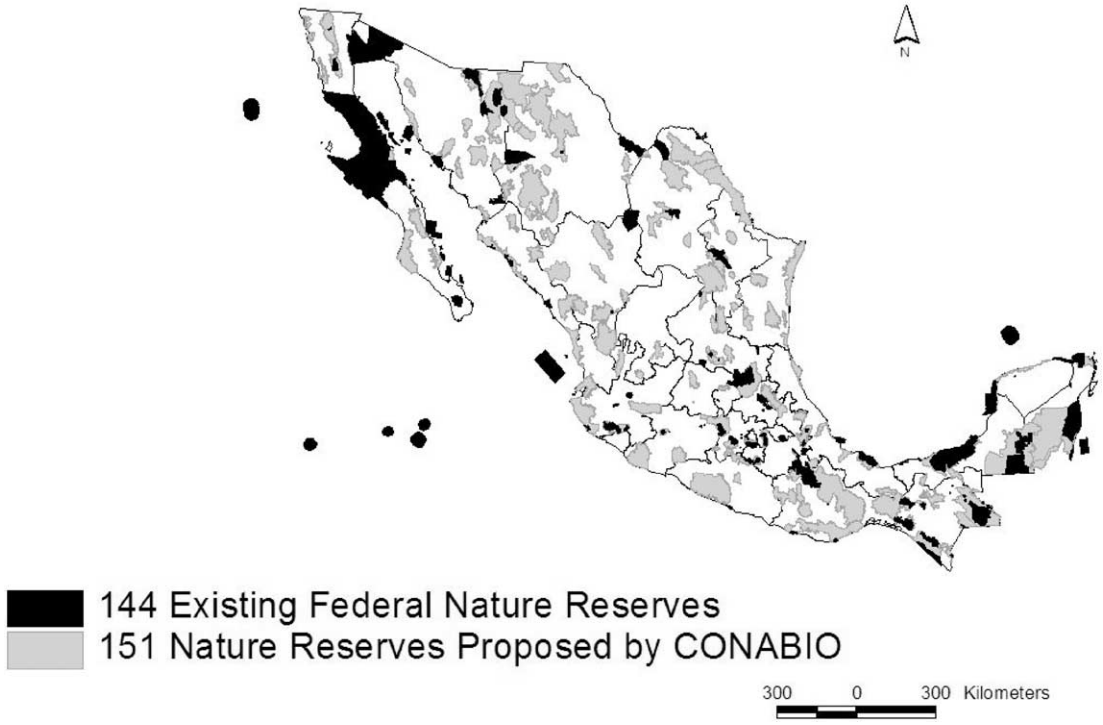

Fig. 1. Existing nature reserve network and the CONABIO (National Commission for Knowledge and Use of Biodiversity) terrestrial proposed areas of Mexico.

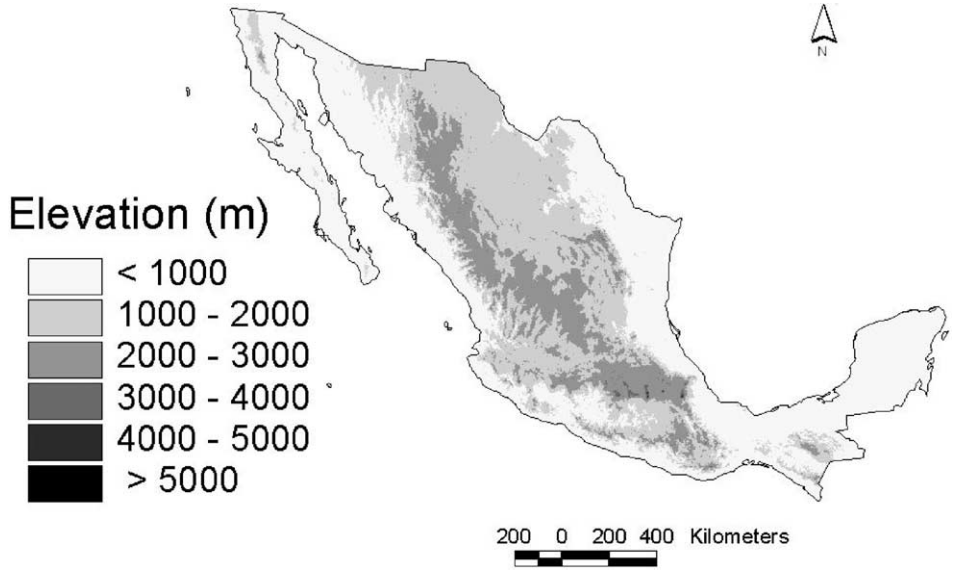

Fig. 2. Elevation features of Mexico.

For the purposes of this analysis we considered that any resource category with at least 12% of its area protected was "adequately protected". We chose this level of protection because it appears to be the most widely used conservation target in similar types of analyses (Wright and Mattson, 1996). We chose this standard in order to make our results comparable to other natural resources conservation studies but we do not suggest that this figure has any established scientific validity.

3. Results

The existing system of nature reserves adequately protects lands with elevations >3000 m. Between 26 and 100% of these high elevation lands are found in the reserves, however, they represent $<1\%$ of land area of the country. Combining the existing 144 nature reserves with the proposed CONABIO additions, would increase the percentage of the land area in Mexico nature

reserves to about 27.4% and would adequately protect all terrestrial elevation categories with the exception of the 0–200 m category (Fig. 3). There are 22 major soil types mapped for Mexico. They have been grouped into three broad productivity classes. The six types considered to be the most productive soils in Mexico, cover 22.4% of the country. However, only 4% of their area is included in existing nature reserves. Rather most of the existing nature reserves contain soil types that are of medium to poor productivity. Establishing the proposed protected areas would slightly alter this situation placing 20% of the most productive soil types in nature reserves (Fig. 4). These findings are similar to those of other studies that have examined the distribution of nature reserves with respect to elevation and soil productivity, i.e. most reserves are located in high elevation regions on steep slopes and on the poorest soils that are arguably of lowest economic

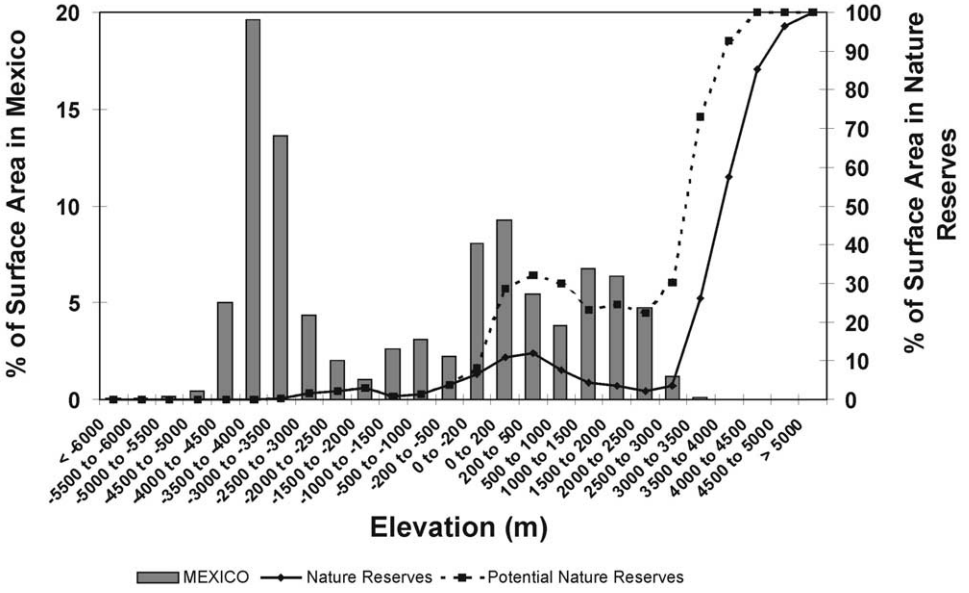

Fig. 3. Percentage of surface area in elevation ranges of Mexico, in the 144 existing nature reserves, and combined with the 151 CONABIO terrestrial proposed areas.

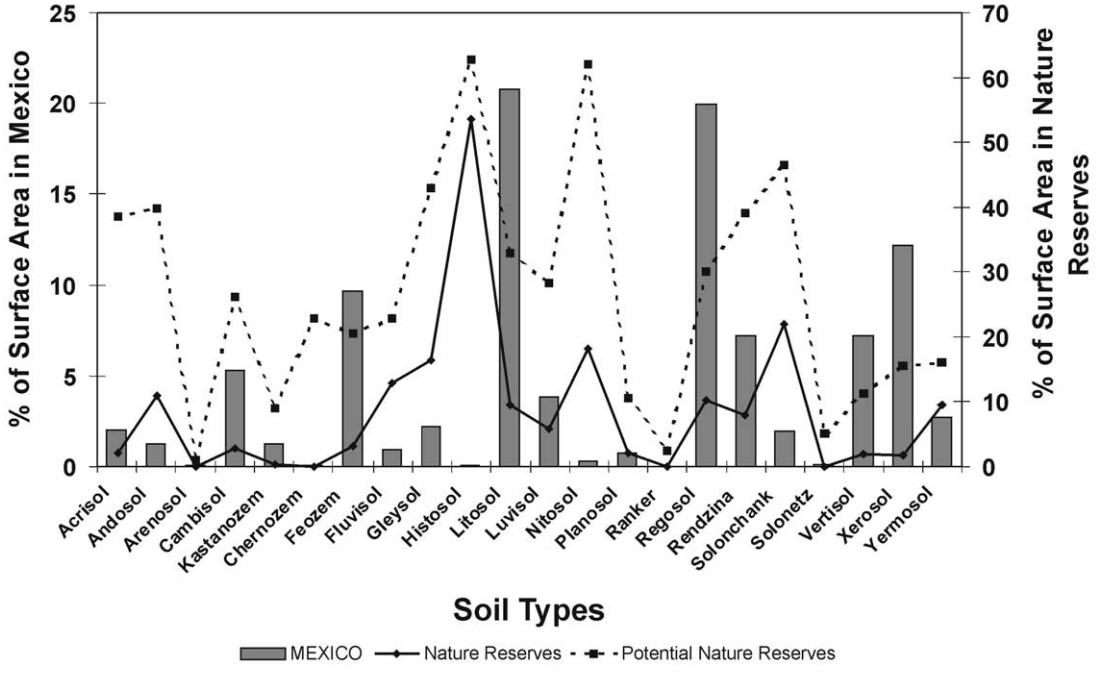

Fig. 4. Percentage of surface area in soil types of Mexico, in the 144 existing nature reserves, and combined with the 151 CONABIO terrestrial proposed areas.

value (Hunter and Yonzon, 1993; Pressey, 1995; Scott et al., 2001).

The nine potential vegetation types of Mexico provide meaningful ecological subdivision of the country that integrates the influence of plant community, species composition, climate, slope, elevation, and soil types. To protect biodiversity in the country, it is important that an adequate sample of each region be represented in the nature reserves. Only one type meet the 12% standard in the existing nature reserves, but all divisions exceed this standard when the proposed areas are included in the analysis (Fig. 5).

The analysis of the land cover map of 1996 showed that mangrove, tropical wet forest, and the gypsophilous and halophilous vegetation exceeded the 12% standard in current reserves, while xeric shrubs, despite covering approximately 30% of Mexico's territory has only 11% of its surface area contained in nature reserves. The proposed areas will exceed the 12% standard for all natural vegetation types (Fig. 6).

4. Discussion

Our analysis included a diverse array of individual biophysical variables and as well as broad subdivisions. Both individual variables and broad categories were included in the analysis, because we felt it would increase our ability to determine how well the range of variation within species and communities are captured in the existing and proposed nature reserves.

The greatest area in existing nature reserves is located in low elevations (0–500 m) but these regions represent less than 12% of the land area found at that elevation. In contrast, the high elevation regions (> 3,000 m) have 73% or more of their area protected. However, these mountain areas represent less than 1% of Mexican territory. The primary gaps in the existing reserve network of Mexico occur mainly at lower and intermediate elevations (<3,000 m) with xeric, tropical and temperate (oak forests and cloud forests) ecosystems, and high productivity soils. Unfortunately, as in many other tropical less-developed countries, these are the areas that typically face high rates of deforestation and landscape fragmentation-factors which add urgency to their protection (Maddock and Been, 2000; Menon et al., 2001).

The proposed nature reserves greatly increase the proportion of protected lands in the country, and significantly improve the protection of reserves. However, even if over 27% of the land area in the country were placed in reserves, important gaps in the protection of certain habitats would still exist because in many cases the proposed reserves would overlap on the existing reserves. In addition, the question of whether this system of reserves would capture the range of (i.e. genetic, morphological, and behavioral) variation found in species and are large enough to maintain the evolutionary potential of self-sustaining populations remains unanswered. This is why we believe that refinements and additions to the proposals made by CONABIO are needed. We are also concerned that if all the proposals are enacted, the opportunity to add

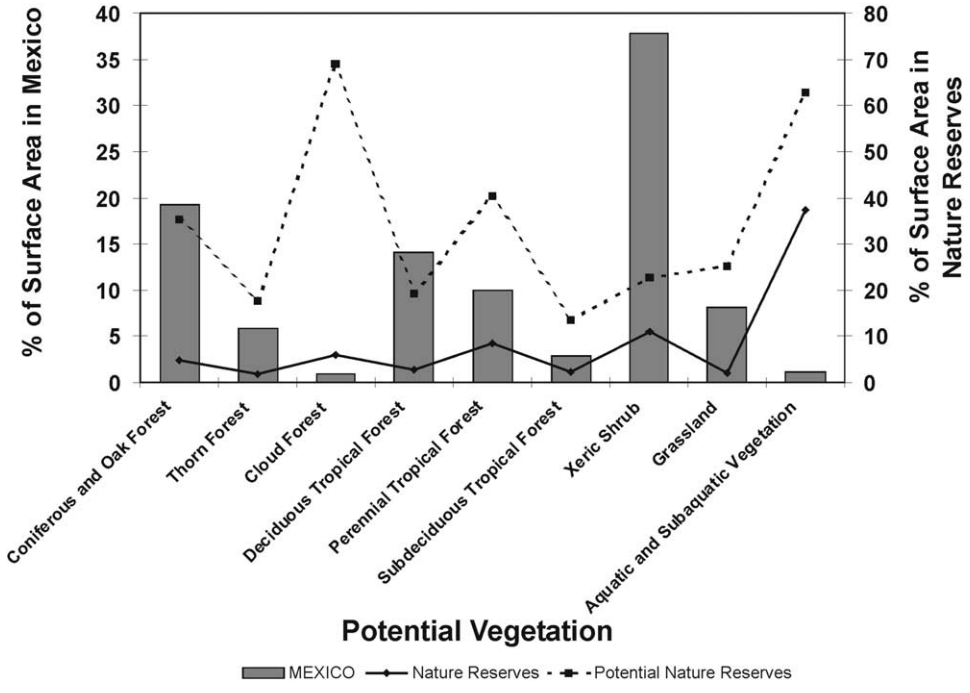

Fig. 5. Percentage of surface area in potential vegetation types of Mexico, in the 144 existing nature reserves, and combined with the 151 CONABIO terrestrial proposed areas.

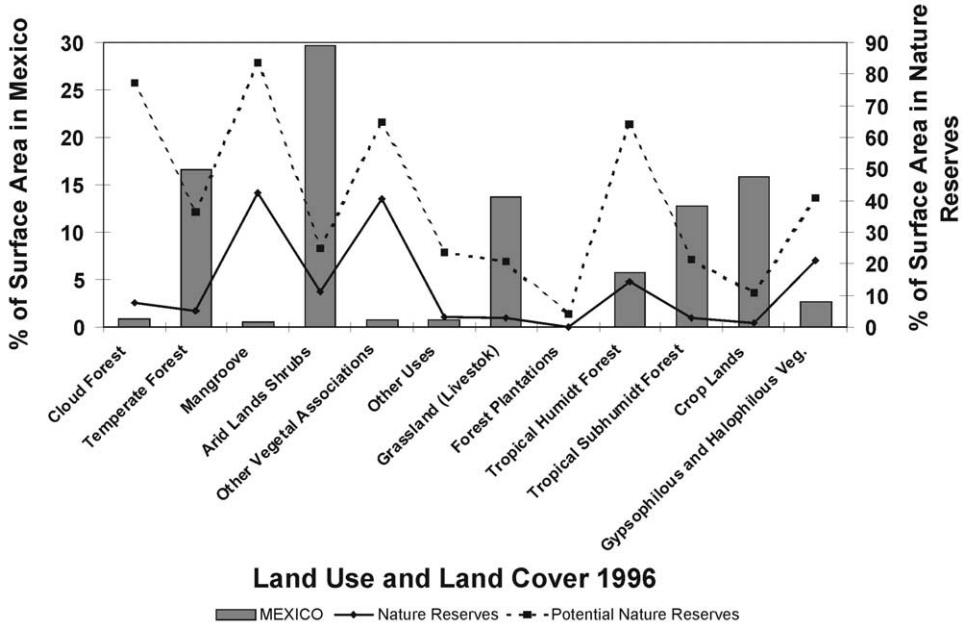

Fig. 6. Percentage of surface area in land use and land cover of 1996 categories of Mexico, in the 144 existing nature reserves, and combined with the 151 CONABIO terrestrial proposed areas.

new areas in the regions where gaps exist may be limited.

Moreover, from the States perspective, the eventual inclusion of CONABIO terrestrial priority areas, would leave important gaps in biodiversity protection, as was shown for Tamaulipas and Nuevo Leon (Cantú et al., 2001).

Although we have shown the important biological value of establishing additional reserves in Mexico, we have not and essentially cannot address the socio-economic realities of establishing any or all of the proposed reserves. A major concern is that the areas where major gaps in the proposed reserve network exist are often the same areas where the majority of the human population resides, and thus the creation of new reserves in these areas will be difficult. Indeed, past experience has shown that even maintaining the existing Mexican reserves in areas of high human pressure has been difficult. For example, 69,000 ha of the Cumbres de Monterrey National Park, adjacent to the city of Monterrey and containing a population of 3.5 million people, was recently taken out of park status because of the expansion of the city.

We consider that the best approach for adequately protecting the biodiversity of Mexico is to develop a comprehensive conservation plan for the entire country, based on this analysis and more detailed information about land cover and species distributions; including the experiences in nature reserve prioritization in other developing countries (Maddock et al., 2000; Brooks et al., 2001). We plan on doing this as next step in this project. In undertaking this effort, we further recognize that protecting isolated areas without considering linkages and corridors between may be futile in long term (Powell et al., 2000).

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